Improving Current Math State of Knowledge for First Year Students

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Abstract

In recent years, a decreasing mathematical knowledge is observable among first year university students. At the same time, the number of students starting their studies at universities is currently increasing. One of the most important factors of success at least for technical studies is the mathematical competence. Therefore we see the improvement of these skills as an important task for today's university education. This paper describes a Moodle based approach that allows the measurement of individual mathematical competence at the beginning of a coaching process to continuously increase the mathematical skills of university students. Here, we combine the use of presence learning, individual feedback of the current math skills of each student and adapted learning advices together with up to date e-learning material. Technically, the system is integrated in Moodle through database extension, filter programming and use of graphic libraries, together with a recommender system for adapted e-learning material. This paper describes details of the technical implementation and provides results of a first evaluation.

Keywords

math education, online evaluation, coaching, adaptation, feedback system

Introduction

Most of the university professors report a decreasing mathematical knowledge among first year university students, while, at the same time, the number of students starting to study at universities is currently increasing. On the other hand, the professors that teach the first year students argue that the most important factor of success in technically oriented study programs is the mathematical competence of the students. Therefore, the improvement of these skills provides an important task for today's university education. In this paper we describe a Moodle based approach to measure the individual mathematical competence of students right at the beginning of a coaching process that allows to continuously increase the mathematical competence. In order to improve the results we combine the use of presence learning, individual feedback of the current math skills for each student and adapted learning advices together with up to date e-learning material. The technical basis of the system is integrated in Moodle through database extension, filter programming and use of graphic libraries, together with a recommender system for adapted e-learning material.

One reason for this development is the duration of pupils in school, which is reduced from 9 to 8 years for secondary education in most of the Federal States in Germany. A second reason is, that new students with more vocational than educational background are permitted to start studying.
Beside this challenge the mathematical competences of these students are decreasing as shown in Table 1 (Knospe, 2011).
In a standardized mathematical test at the first day of their university education the mathematical competence is evaluated. Since 2002 this test is used at the Universities of Applied Science in NRW. Ten basic mathematical items (solving equations, quadratics, powers and logarithms, linear equation …) have to be solved.
The average value of solved items is shown in column three of Table 1. The already disappointing results in the year 2002 are continually getting poorer.

Table 1: Results of math-examination before the start of studies in NRW

Year	Number of participants	Number of points (all participants)	Abitur/intensive math course	Abitur/basic math course	university of applied sciences entrance qualification
2002	2936	3.99	5.06	3.72	3.51
2003	3240	3.86	4.98	3.35	3.49
2004	2741	3.52	4.95	3.01	3.17
2005	1626	3.65	4.83	3.68	3.27
2006	2151	3.66	4.80	3.53	3.28
2007	2593	3.51	4.62	3.24	3.23
2008	2941	3.54	4.78	3.42	3.14
2009	2565	3.86	5.30	3.75	3.38
2010	2493	3.28	4.58	3.00	2.89

A maximum of 10 points are possible

Especially in MINT-studies (mathematics, informatics, science and engineering), the failure- and termination-quote is very high. In combination with the short duration of bachelor degree programs compared with the duration of diploma degree programs before, the number of graduates and their level of competence is decreasing and in the result dissatisfying. The approach described here utilizes an individual matched mathematical coaching for each student in order to improve and equalise the qualifications of all students before the beginning of their university education. The specific idea of our approach is the direct control of all activities through a mathematical test in the beginning. After a semiautomatic evaluation the test results are stored in the Moodle database and used as an individual basis for all recommendations, which are automatically generated. Through controlling and fusion of all online- and offline-processes the learning results and the satisfaction of students and teachers with our strategy is higher than in using standard unadapted strategies. This paper starts with a section about related work, continues by describing detailed information about the technical implementation, shows results of a first evaluation of the described system and concludes with an outlook towards planned future work.

Related Work

Our approach uses a blended scenario and skill-adapted learning strategies. Considering the psychology of learning our research is related to the ideas of self-regulated learning as described by Dreer (Dreer, 2008) and Benz (Benz, 2010). In the learning management system the personalized feedback and individualized learning advices are the key elements of our system. Here, we provide a similar approach, with respect to personalized feedback, as Saul and Wuttke presented (Saul & Wuttke, 2011). Furthermore, we try to enhance learners motivation since according to Norman D. & Spohrer J.(1996) this is the key factor for the learning outcome. Following the ARCS-Model of motivational design, which was created by John Keller (Keller, J. M., 2010), the improvements will fit to the key components attention and satisfaction. These are central aspects of serious games, which use interactive audio-visual components to enhance user experience. Relevant for our work is the approach of Jarvis and de Freitas, who reflect the in-game feedback and its effect on learning transfer improvements (Jarvis, S.& de Freitas, S. 2009)

Architectural Approach

The architecture of our approach consists of three parts: the survey environment, the database enhancement and evaluation & feedback instruments. In the following (see Figure 1), these three parts are described in more detail.

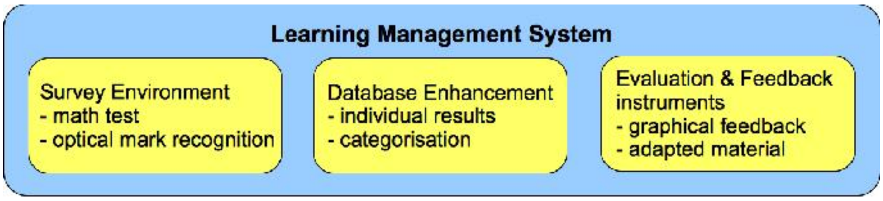

Figure 1: Architectural Approach, three parts bound through the LMS

Survey environment

The mathematical test, as shown in Figure 2, is done as paper and pencil test to prevent the disadvantage of online test proceedings, like distortion through plausibility considerations of multiple choice-questions (Lau et al., 2011), or a subject being forced to use an equation editor to get the correct mathematical representation, which provides an additional barrier.

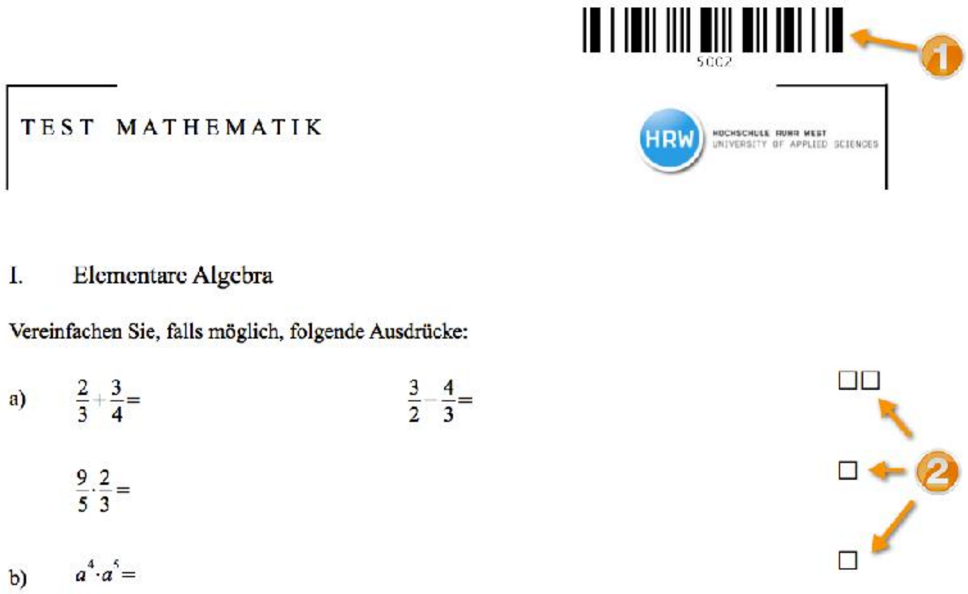

Figure 2: Mathematical Test (Optical Mark Recognition: 1 – codabar for identification, 2 – checkboxes to capture the results)

With this test the elementary calculation techniques are verified, because here we have seen the most stressing problems of our students during their first year of studies.

Table 2: Topics of math test

Topic	number of items
Fractions	3 items
Arithmetic with powers and radicals	3 items
Logarithm laws	2 items
Transforming equations	3 items
Solve quadratics	1 item
Build inverse functions	3 items
Elementary power and logarithm values	6 items
Pythagorean theorem	1 item
Definition of trigonometric functions at the triangle	4 items
Drawing of functions	9 items
Symmetrie of functions	2 items
Unit conversions	2 items
Elementary derivatives	5 items
Elementary integrals	3 items

Usually, their lack of knowledge of elementary calculation techniques prevents them to follow a wide range of their lessons of first university year adequately. The different topics of the test are shown in Table 2.

In our case, we used a semi-automated evaluation of the test results, meaning that the tests were manually corrected and automatically read and stored in a database by optical mark recognition. To identify the test itself and the page number a codabar code on top of each page is used (Figure 2:1). For each answer the correctness of a result is marked in a checkbox at the right site and , after the mark recognition process, stored in the database (Figure 2:2).With the open source tool quexf (Australian Consortium for Social and Political Research Incorporated, 2010) for optical mark recognition the data was captured for the database. During the last run, taken before the winter term 2011/2012, a group of N = 335 students performed the test. Each of the students, starting with different studies, had thirty minutes for doing the test. Later on, the herby gathered data was used in order to group the students according to their individual math knowledge and to create adapted e-learning material in order to increase these skills. Since all learning activities are based on a blended learning concept the presence learning is also controlled by the test results. For the presence learning the students are grouped with students of similar competences, with respect to the test results. For students with low level abilities the course was realized with less then ten participants and with a duration of three weeks. With rising abilities of the students in a group the maximum number of participants was increased and the duration decreased as shown in Table 3.

Table 3: Presence learning group arrangement

Group number	Student ability level	Maximum of students in one group	Duration of lessons
1	low level	10	3 weeks with 6 hours a day
2	medium level	20	2 weeks with 6 hours a day
3	high level	35	1 weeks with 6 hours a day
4	very high level	all	only the use of e-learning

Database enhancement

The test result for each student, the test items and two different categorisations of these items are stored in five additional tables in the Moodle database. This database enhancement is the basis for the different dynamic, login dependent feedback and controlling instruments. Figure 3 shows the enhancement of the Moodle database.

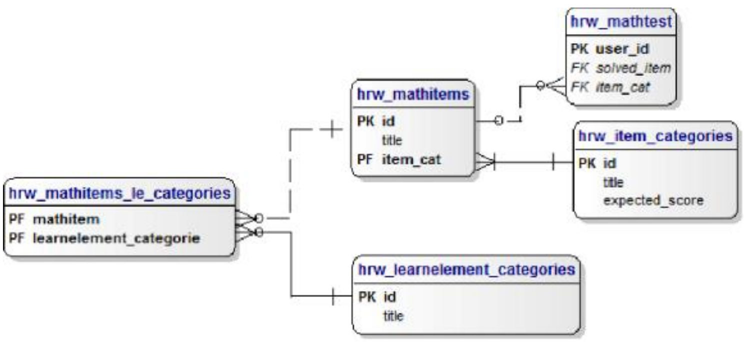

Figure 3: Entity relationship model of the Moodle database enhancement

The solved items for each student, who is identified by his user_id, are stored in the table hrw_mathtest. The solved items reference to the table hrw_mathitems, which includes all items of the math test identified by its id and a title for this item. To group these items by the categories of the math test and by the categories of the learning elements in the Moodle-course, references to the tables hrw_item_categories and hrw_learnelement_categories are included.
From the candidate number in the test result table the login-names, and the passwords are automatically generated and used as data source for serial letters to inform students about their login to get into the coaching platform.

Evaluation & feedback instruments

Each student gets his personalized view, when he is using the Moodle learning management system (see Figure 4). After an introduction of the course and its objectives (Figure 4:1) the personal results and individual recommendations (Figure 4:2) are presented. This is followed by adapted mathematical learning material (Figure 4:3) of different levels (Figure 4:5) and the visualisation of the own ability in each subject. This visualisation provides the central feedback for the students.

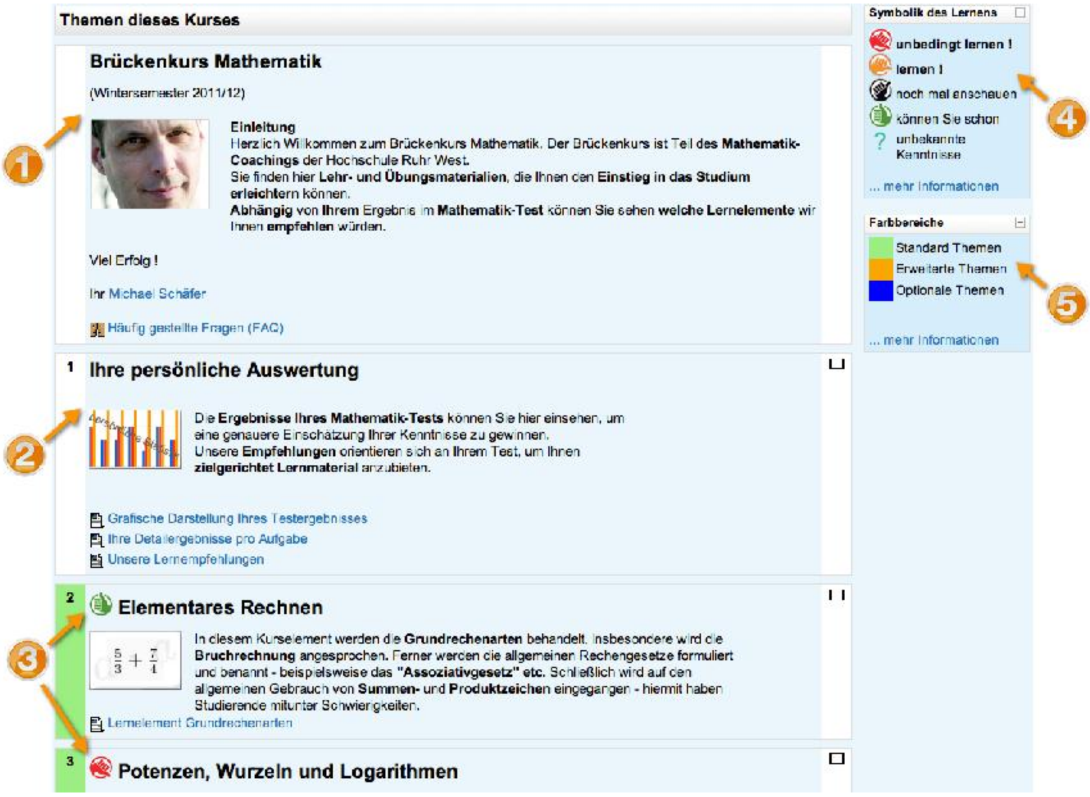

Figure 4: Part of math course (1 - introduction, 2 – personal math test results , 3 – learn elements with competence feedback, 4 – feedback symbolic, 5 – different math levels)

Figure 5 shows the graphical representation of the students' personal result. Here, the items are grouped in categories and for each category the personal result (first column), the average result of all students (second column) and the expected result (from their teaching professors) is shown. The average result is helpful for the students in order to reflect their knowledge in comparison to the other students, and, at the same time, in relation to what their future teaching professor assumes the students should know about a certain topic in order to reasonably

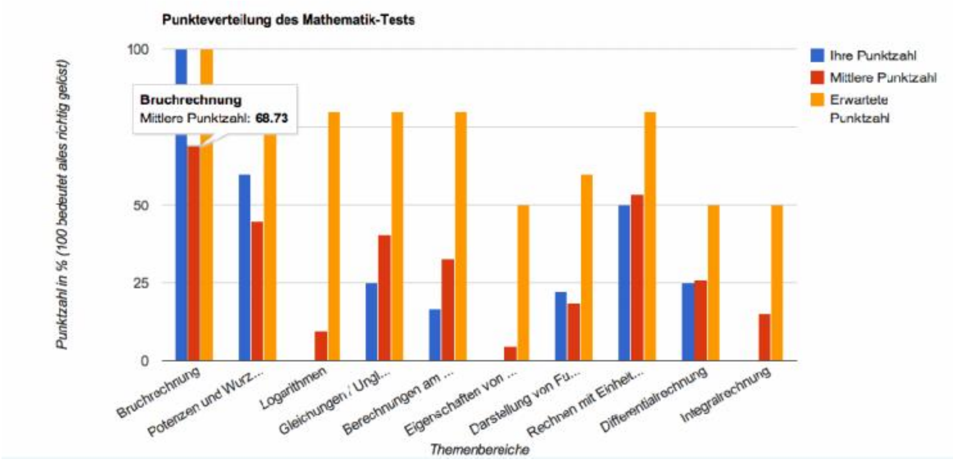

Figure 5: Personal math test result (Blue (first column) – own score of the student (depending on Moodle user), Red (second column) – average score of all students (N=335), Orange (third column) – expected score by teachers)

Due to these results and supported by feedback symbols (Figure 4:4) learning material for all relevant topics is implemented. It is divided into 13 topics with about 600 pages and 180 exercises and solutions. The first topic 'Elementares Rechnen' is shown at the bottom of Figure 4. Introduced by a symbol and a brief description of this topic the learning element is presented.

Implementation

The implementation is based on a modification of the PDCA cycle (Deming, W., 1986). Figure 6 shows a simplified float chart of the underlying implementation model. Based on the math-test in the beginning the students go through a cyclic learning and testing process until their abilities fulfil their needs.

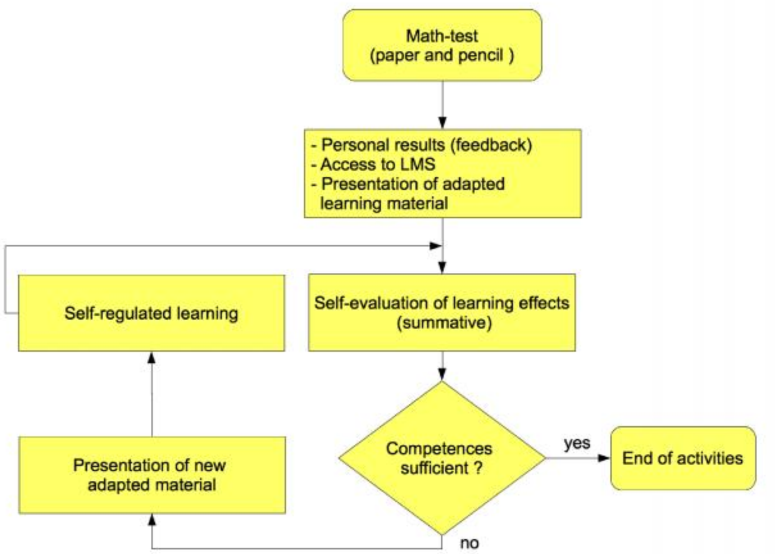

Figure 6: Flow chart oft the process-implementation in the Moodle-platform

The technical implementation is done by Moodle filter programming. An author is able to include the individual results of a student by using simple tags when editing course elements. A simple example is shown in Figure 7, where the number of correct items should be shown in a text page. Therefore the author added the phrase '[mathtest]mathresultpoints[/mathtest]', where he wants to show the number of resultpoint of the logged in student. The phrase is replaced by the correct result as shown in Figure 7 on the right side.

For the tags square brackets (‘[mathtest]... [/mathtest]’) are uses, because in this case the editing works also with WYSIWYG editors.

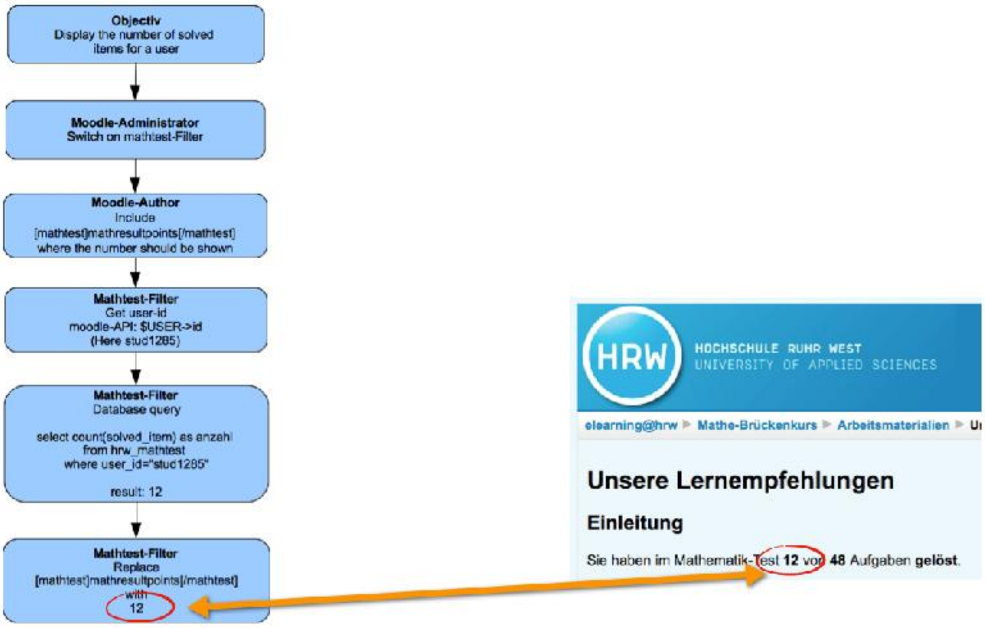

Figure 7: Moodle filter example to show the number of solved items

On the server side the implementation is done by php. Here, we deployed the implementation for the dynamic generation of results, which are based on the math test. Depending on these results different cases are analysed by client side programming and for example different adapted learning advices for the students are presented.

Evaluation and Results

As formerly described we had the first run of our mathematical coaching in the year 2011 with N=335 students. The main focus of the first evaluations was to observe acceptance and satisfaction of our students and to get feedback for necessary improvements.

Method

Different methods were used to get feedback to enhance the learning process and its performance. The teachers, the student management, which did all organisational tasks and the professors of the first university educational year took part in informal assessments. With a formative assessment our coaching approach was evaluated to test the usability and acceptance of the system and to get an idea, if the students believe, that this kind of system is helpful, in order to increase their mathematical competence. The formative assessment with the coached students was realized two month after the coaching process as a paper and pencil survey. The survey consists of 27 items with 12 different dimensions. 14 items are referring to HIELVE II (Rindermann, 2009), three items (about the influence of group size) are referring to (Arnold, 2005).

Additional six items are self created, dependent on the university where the evaluation was performed and one item of the subdimension educational background. In general a seven-level-Likert scale (Likert, 1932) with items from 1: strongly disagree to 7: strongly agree was used and trough explorative factor analysis (principal component analysis) the loading of each items on their dimensions were pretested, before the average for this dimension was determined.

First results

The first evaluation was only done with a small part of the participating students (N=49). First of all we were not sure, if a mathematical test, before the studies are starting, will be accepted. With an average value of AVG=5.42, a standard deviation of SD=.93 and a median of SM=6 the students seem to accept the test as reasonable. A closer look to the different parts of our learning concept shows that the visiting of the presence-learning courses was profitable for the students with an average value of AVG=5.84, a standard deviation of SD=1.25 and a median of SM=6. In a 5-level-Likert scale the students estimate the influence of the small group-sizes with an average of AVG=1.7 and a standard deviation of SD=1.37 (1: very positive, 2: positive…).

For the question, if using the e-learning platform was profitable to them, the students estimated with an average of AVG=3.74, a standard deviation of SD=1.39 and a median of SM=4. So only a slightly positive result was measurable. Whereas the visiting of the presence-learning course in combination with using the e-learning platform was profitable for the students with an average of AVG=4.93, a standard deviation of SD=1.47 and a median of SM=5. Different further dimensions were evaluated with accordingly loading items. The overall-feedback for fitting the demands of each student, self-observed learning-effects and helpfulness for the first year courses was positive. The free text answers of positive and negative critique and improvement proposals also showed that the students liked the overall concept of the presented approach.

Conclusion and Future Work

Our first implementation of a blended learning mathematic coaching concept seems to be promising.
The first results of the evaluation are positive. We plan to use them to further enhance the concept to improve the mathematical competences of the students and the technical implementation.

The adaption of e-learning-material, the personalized feedback and the arrangement of learning groups depending on the competences of the students have positive effects on the improving of current math skills of first year students. Dissatisfying is the only slightly positive acceptance of the e-learning platform itself. Future work will improve the user experience as the main factor for motivation. Therefore, experiences on serious game development will be transferred to enhance the Moodle course. Direct audio-visual feedback, the use of more self test possibilities and dynamic adaptions will support the usage. In conclusion, this paper presented the implementation of a learner centred adaptable blended learning concept. This solution has the potential to significantly improve learning effects. These effects will be controlled by summative evaluations. Still, some efforts of future work are necessary in order to enhance and evaluate this concept.

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